NASA Briefing to USAF
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Automated Meta-Aircraft Operations

FOR A MORE EFFICIENT AND RESPONSIVE AIR TRANSPORTATION SYSTEM

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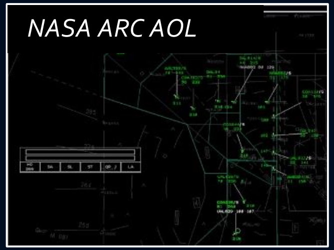
Innovation

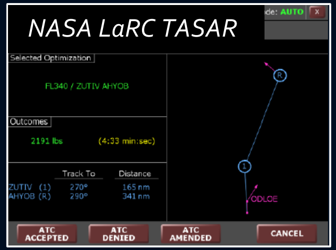
Transform the Air Transportation System through the introduction of civilian transport Meta-Aircraft.

Air-to-Air Data Sharing

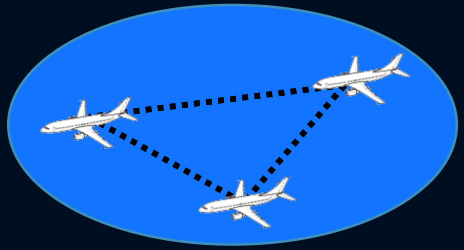
Autopilot Systems



Real-Time Scheduling/ Routing Tools



Automated Flight Planning System



Meta-Aircraft Concept

Big Question: How will automated meta-aircraft operations enable a cleaner, more efficient, and more responsive air transportation system?

Motivation

2010 Eyjafjallajökull Eruption

In 2010, the explosive eruption of the Eyjafjallajökull volcano in Iceland closed UK, European and North Atlantic airspace for 6 days. Over 95,000 flights were cancelled.

(University College London Institute for Risk and Disaster Reduction)

2014 Chicago ATC Center Fire

In 2014, a fire forced the Chicago Air Route Traffic Control Center to suspend operations for 4 hours, cancel over 1,700 flights, and transfer responsibility for thousands more to regional control centers. Delays cascaded across the country and the effects persisted for weeks.

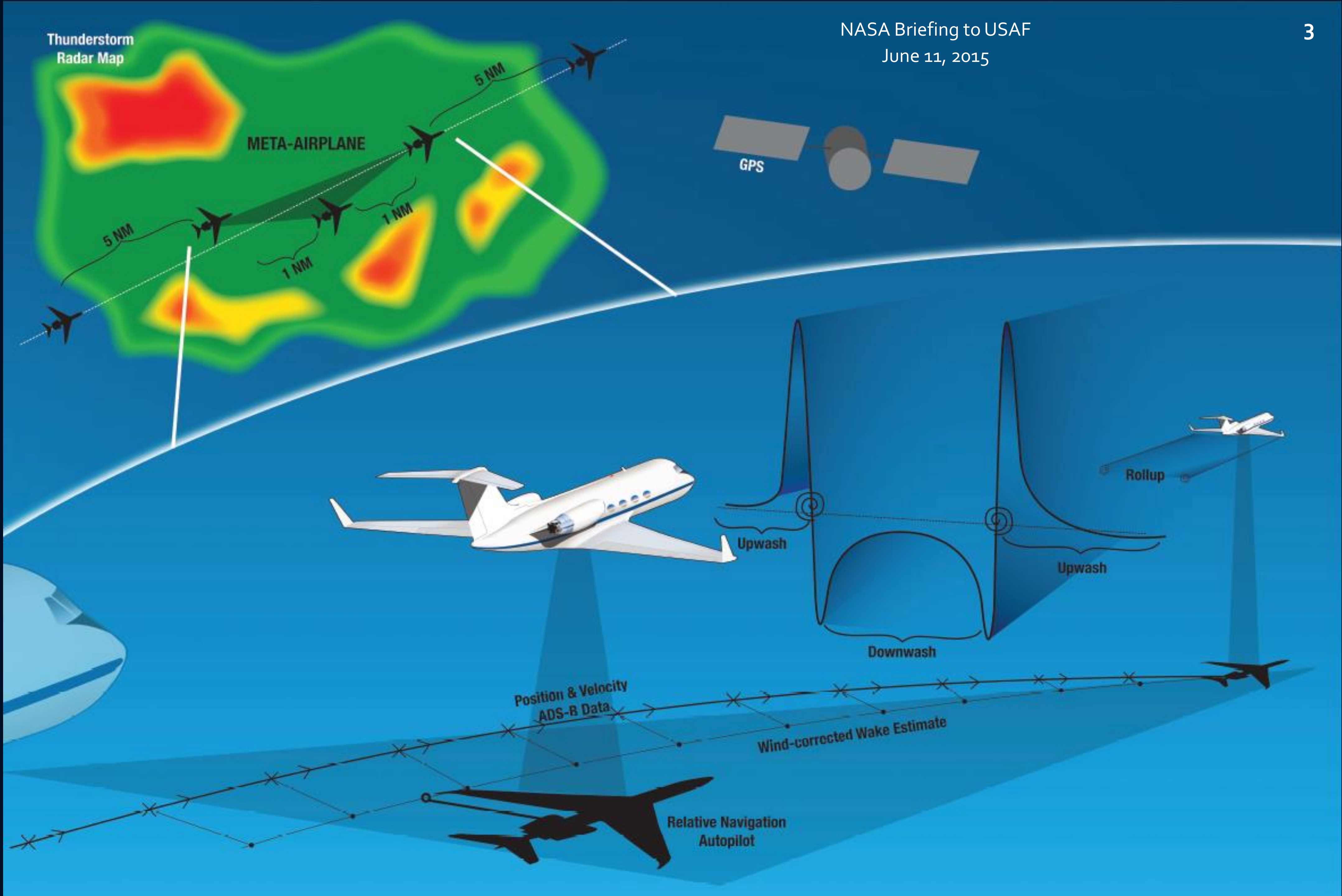
(Reuters, Chicago Tribune)

Fuel Costs / Environmental Impact

By 2011, fuel made up 30% of airline costs ($50B). Energy prices are expected to continue to rise over the long term. Air transportation accounts for 2% of global CO_2 emissions, and will increase with continued growth in world-wide aviation needs.

(NASA Aeronautics Research Mission Directorate Strategic Implementation Plan)

Meta-Aircraft Concept



Convergent Technologies

Modern Digital Avionics, Data Sharing Networks, and Advanced Operational Concepts:

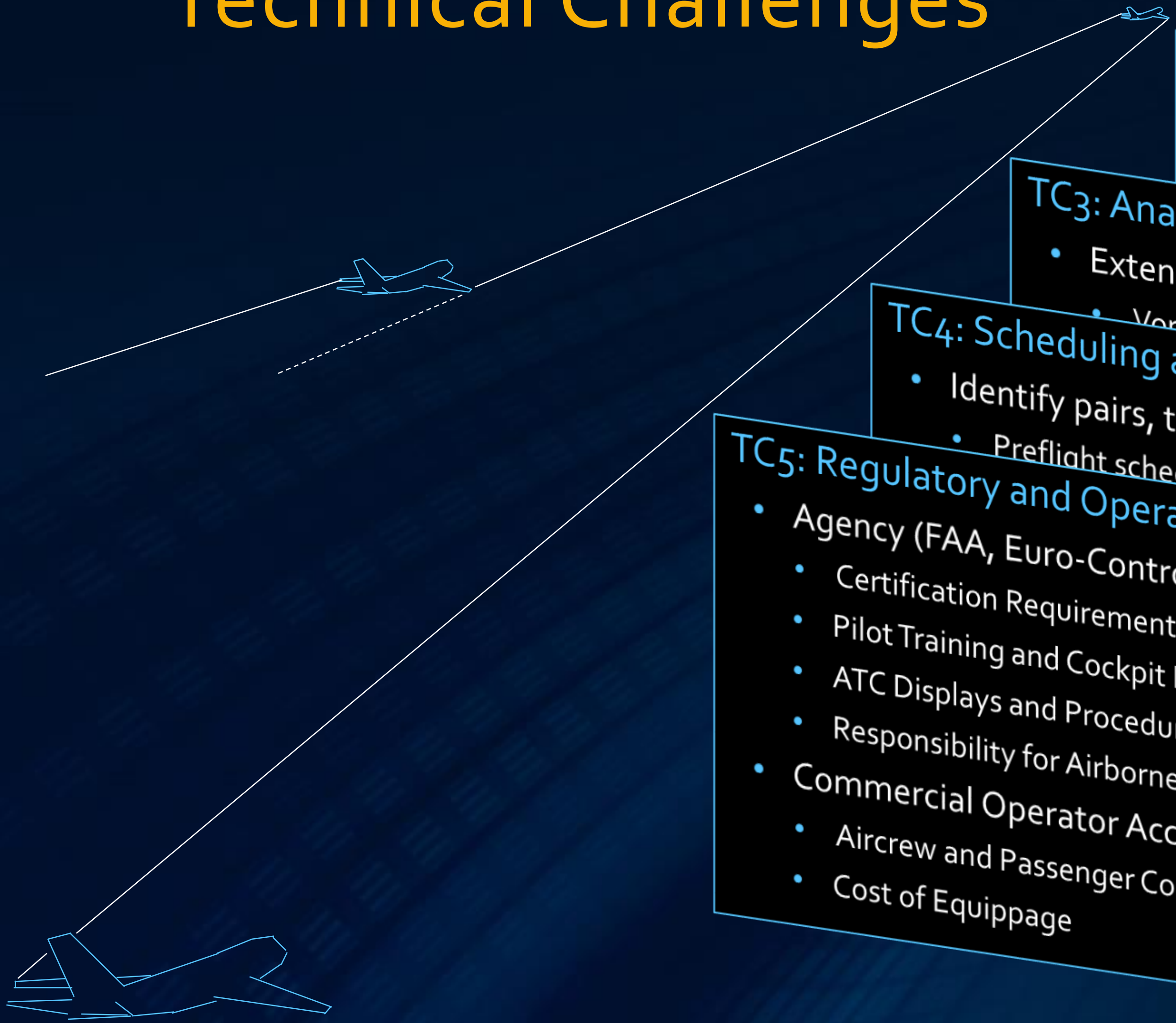
- By 2020 all aircraft in Class A,B and C airspace will be equipped with ADS-B Out to transmit position, velocity and intent.
- The FAA has approved ADS-B In flight deck applications to assist the pilot with Interval Management, In-Trail Procedures, and Traffic Awareness.
- In 2013, two C-17 transports demonstrated a 10% reduction in fuel usage on a flight from Edwards to Hickam AFB using prototype wake surfing technology.

FAA 14 CFR Part 91

ACSS SafeRoute®

AFRL/DARPA/Boeing
$AVE Project

Technical Challenges



TC1: Commercial Airframe Benefits and Impacts
- Does the demonstrated benefit for military aircraft (F-18, F-16, T-38, C-17) translate to airliners?

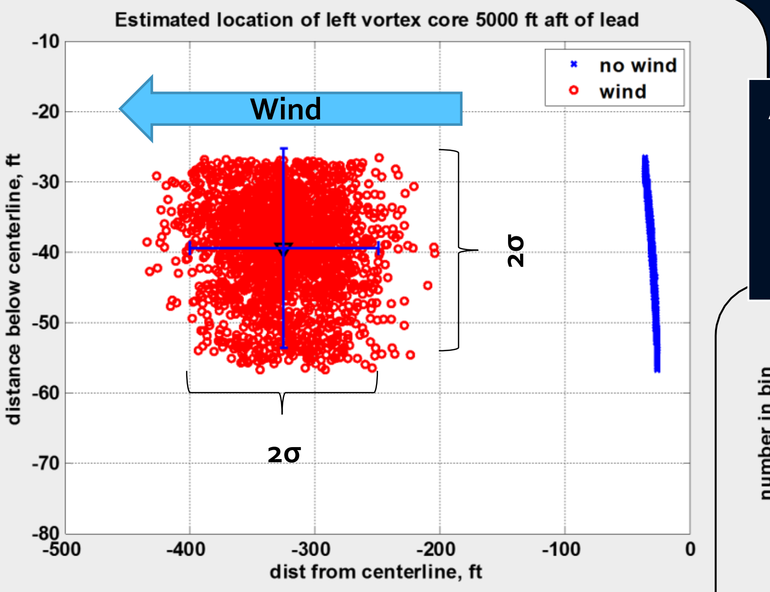
TC2: Suitability of ADS-B for Wake Surfing
- ADS-B is primarily an air-to-ground data link for ATC situational awareness.

TC3: Analysis, Design, and Control Algorithms
- Extended Near-Field Wake Modeling
  - Vortex Degradation → Ride Quality

TC4: Scheduling and Routing Tools
- Identify pairs, triples, etc. of aircraft to form into groups.
  - Preflight scheduling

TC5: Regulatory and Operational Acceptance
- Agency (FAA, Euro-Control) and Union Acceptance
  - Certification Requirements
  - Pilot Training and Cockpit Displays
  - ATC Displays and Procedures
  - Responsibility for Airborne Separation
- Commercial Operator Acceptance
  - Aircrew and Passenger Concerns
  - Cost of Equippage

NASA G-III HIL Simulation

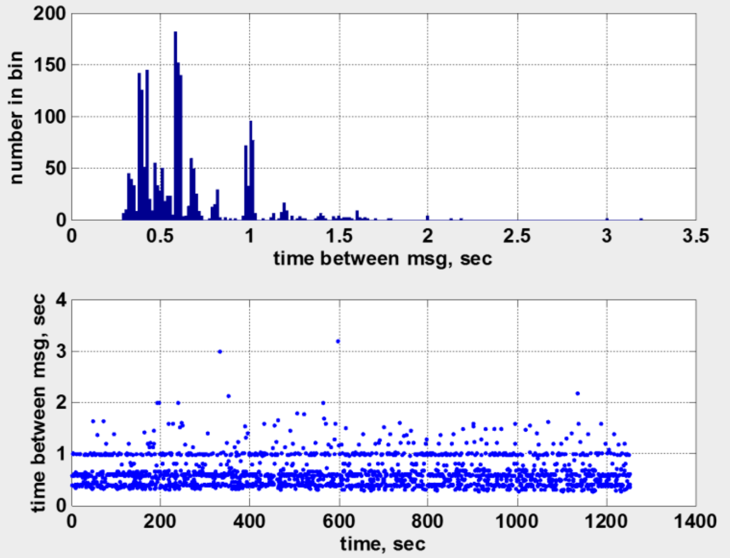


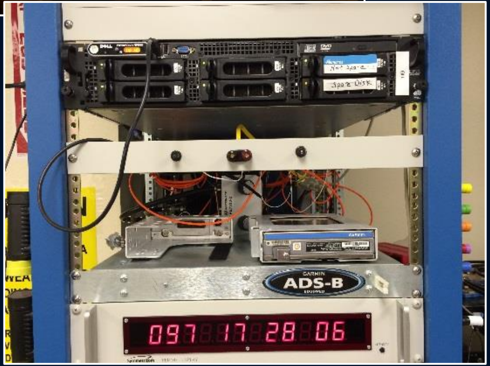
Wake Descent/Drift Study

- ±20 ft vertical dispersal due to wake structure uncertainty
- ±150 ft lateral uncertainty due to wind drift

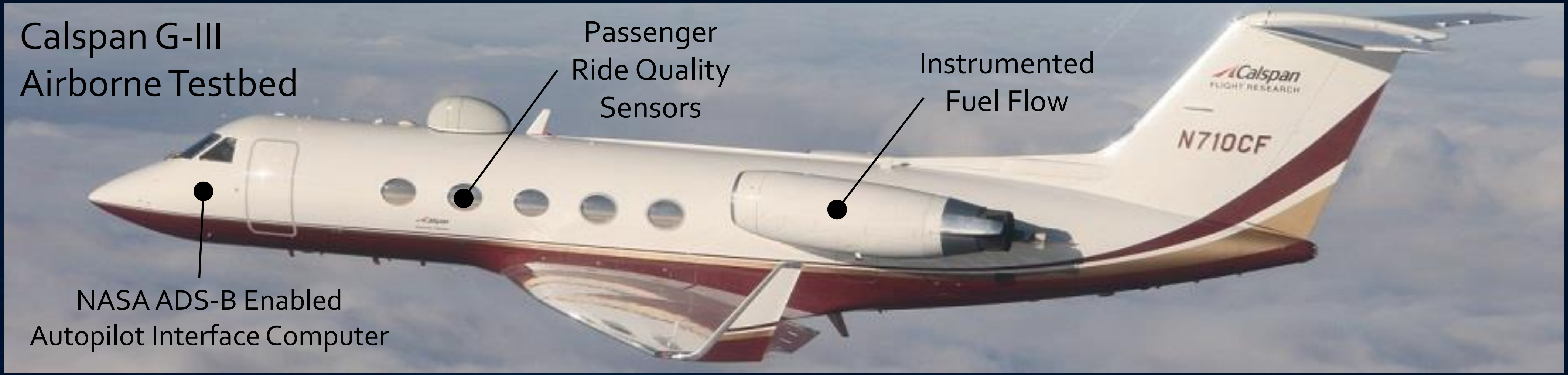
ADS-B Communication Study

- Message clusters at 0.4, 0.6 and 1.0 second intervals
- Occasional intervals > 3 seconds





Flight Tests in FY15-16



TC1: Commercial Airframe Issues

Demonstrate significant, achievable fuel savings with a civilian airframe.

Gather data to correlate passenger ride quality with measured performance benefits.

Collect data on the duty cycle impacts of wake surfing on aileron actuators.

TC2: Suitability of ADS-B

Demonstrate NASA's ADS-B enabled Autopilot Interface Computer for future autonomy applications.

Characterize ADS-B communication in a relevant meta-aircraft environment.

Evaluate ADS-B as a feedback path for autonomous cooperative procedures.

TC3: Algorithms

Validate wake prediction algorithms for descent and wind drift.

Demonstrate commercial autopilot capability for wake surfing.

Evaluate wake estimation and avoidance algorithms.

System-Level Impacts

If successful, Automated Meta-Aircraft Operations will:

- Increase flight throughput by at least 10% during severe restrictions in available airspace. ← ARMD Thrust 1: Safe, Efficient Growth in Global Operations
- Demonstrate a return on investment within the first year for aircraft equipped with wake surfing technology. ← ARMD Thrust 3: Ultra-Efficient Commercial Vehicles

Traceability to Autonomy Research Themes Identified in the 2014 ICAST Report

1. Autonomous Planning and Decision Making
2. Autonomous Vehicle Control and Optimization
3. Real-Time Vehicle-Centric Cooperation and Interoperability

ARMD Thrust 6: Assured Autonomy for Aviation Transformation

Technology Validation Roadmap

Close Formation Flight Research

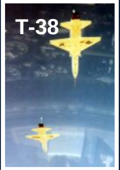
1995 — *German Institute for Fluid Mechanics*

- Proof of concept
- No data link
- 10% power reduction
- Rudimentary peak-seeking control

2001 — *NASA Dryden Flight Research Center*

- Research data link and autopilot
- 14% fuel savings (manual)
- Validated system requirements
- Detailed wake effect mapping

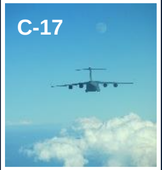
2001 — *US Air Force Test Pilot School*



- Manually flown
- No data link or autopilot
- 9% fuel savings (2-ship)
- Inconclusive 3-ship evaluation

Extended Formation Flight Research

2010 — *NASA DFRC / USAF FTC*



- Proof of extended formation concept
- Production military data link and autopilot
- 7-8% fuel savings (manual)

2012 - 2013 — *DARPA / AFRL / Boeing*

- Modified C-17 autopilot
- Production military data link
- 10% fuel savings (autopilot)
- Wake avoidance algorithms

Path To Commercially-Viable Automated Meta-Aircraft Operations

2013 - 2017 — *Partnership between NASA AFRC, ARC, GRC, and LaRC (proposed)*

- Airspace simulation study
- Hardware-in-the-loop multi-vehicle simulation
- Flight research

Optimal Scheduling and Real-Time Routing Tools

Wake Estimation and Avoidance, Performance Optimization

Suitability of ADS-B for Wake Surfing

Flight Data: Performance and Ride Quality

2018 - 2020 — *Operational Demonstration with Industry Partners (to be determined)*

- Commercial Data Link (1090 MHz ADS-B In and Out)
- Automated Meta-Aircraft functionality integrated with commercial avionics
- FAA participation
- Pilot displays and procedures
- Demonstrate scheduling / routing tools
- Candidate trail aircraft: commercial transport class

Questions?

Technology Stakeholders

Airframe Manufacturers

LOCKHEED MARTIN

BOEING
Letter of Support
In Progress

Avionics Manufacturers

Rockwell Collins
Letter of Support
In Progress

Honeywell

GARMIN

Commercial Cargo/Passenger Operators

FedEx
Letter of Support
In Progress

UNITED
Letter of Support
In Progress

UPS

Safety and Regulatory Community

Federal Aviation Administration

WakeNetUSA

RTCA
THE GOLD STANDARD FOR AVIATION SINCE 1935

Military and International Communities

Air Mobility Command

AFRL
THE AIR FORCE RESEARCH LABORATORY
LEAD | DISCOVER | DEVELOP | DELIVER

NATO
OTAN